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INTRODUCTION

Virginia pine (Pinus virginiana Mill.) is the dominant species on many forest lands in Maryland, Virginia, and the Carolinas. Not many years ago Virginia pine was classed as a forest weed and commonly called "scrub pine" (6). In recent years, the good pulping qualities of its wood, its heavy yields per acre, and its acceptance as sawtimber have led to increasing interest in the productive capacity of Virginia pine by landowners.

This paper reports cubic-yield estimates of Virginia pine stands of various densities, growing on different sites, and with varying proportions of the forest stand in Virginia pine.

Yield estimates for Virginia pine have been published for other localized portions of its range. Slocum and Miller (5) constructed growth and yield tables from data gathered on the Hill Demonstration Forest in Durham County, North Carolina. Church (2) developed yield predictions for pure Virginia pine stands in Prince Georges County, Maryland, and McIntyre prepared yield tables based on data from Pennsylvania (3).

THE STUDY AREA

The study was based upon 161 plots in 51 counties in Maryland, Virginia, North Carolina, and South Carolina (fig. 1). The 105 plots in Virginia, the 36 plots in North Carolina, and the 8 plots in South Carolina were in the Piedmont on typical Piedmont soils. The twelve Maryland plots were located on coastal plain sites.

The plots were systematically located in Virginia pine stands within the counties sampled. Individual plots were tallied and used in data computations only if they contained at least 10 percent Virginia pine in the main crown canopy and there was a reasonably uniform spacing of trees throughout the plots.

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2/ The computational aid of Mrs. Irma B. Ellison, Statistical Clerk, Southeastern Forest Experiment Station, is gratefully acknowledged.

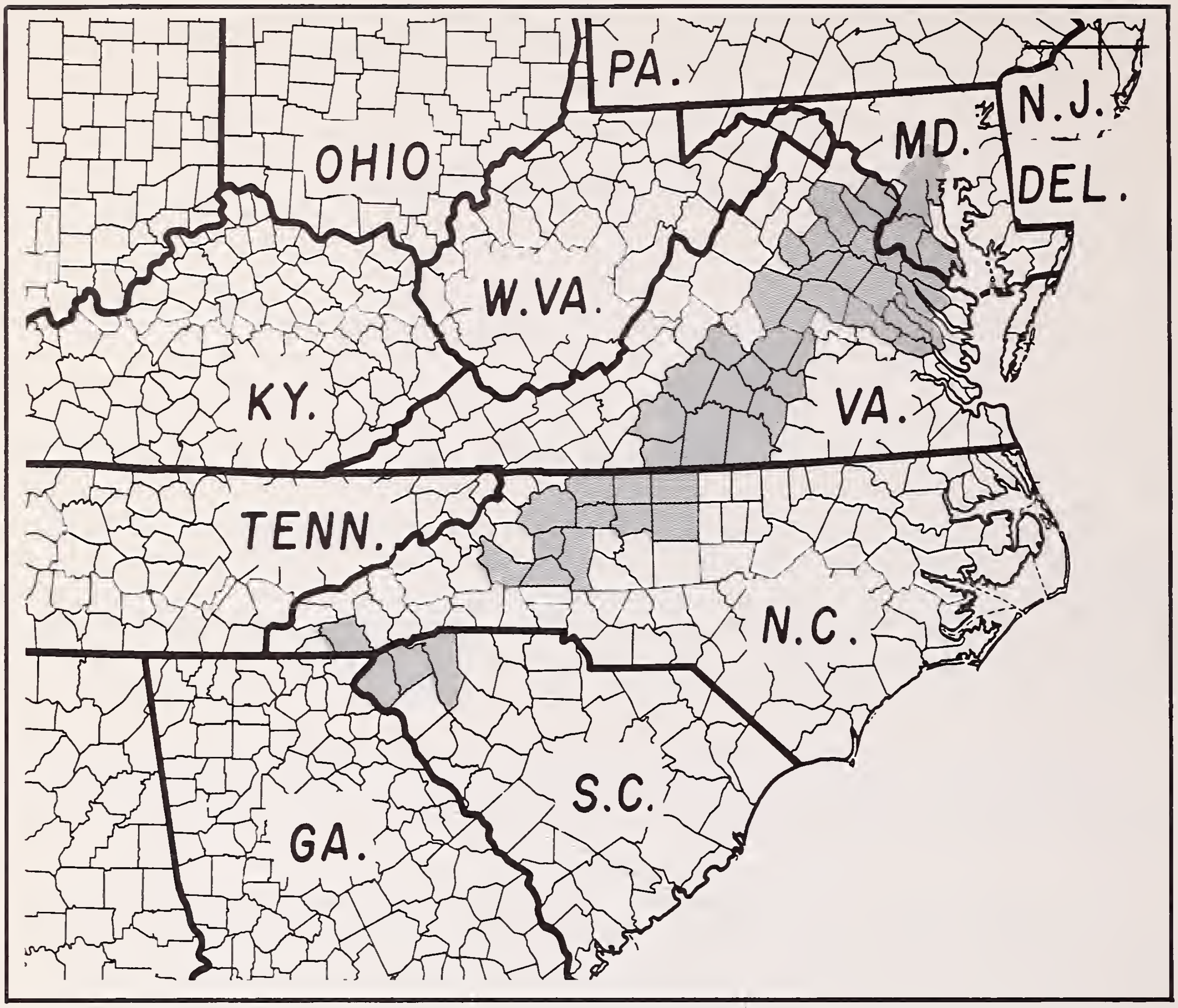


Figure 1.--Location of study plots, by counties, in Maryland, Virginia, North Carolina, and South Carolina.

The stands sampled were even-aged and varied from 10 to 70 years (fig. 2). The majority of plots (80 percent) were in old fields (fig. 3). These fields generally represent the poorest agricultural land, but sometimes are more fertile than the surrounding woodland sites.

Most of the plots showed no evidence of recent fire. Thirty-eight of the 161 plots had been grazed and the majority had indications of cutting at some time. All exposures were represented, but the majority of plots were located on slopes; only 31 plots were located on ridges.

Figure 2.--(A) A typically dense stand of Virginia pine in the North Carolina Piedmont. This 19-year-old stand contains 178 square feet of basal area per acre. (B) A 34-year-old stand near the same location with a basal area of 125 square feet per acre.

Figure 3.--Virginia pine invading an old field near Statesville, North Carolina. The seed source for these sapling-stage pines is the older, even-aged stand on the ridge.

STUDY METHODS

The analyses involved construction of volume tables, preparation of site index curves suitable for calibrating sites on the basis of heights of dominant and codominant trees at 50 years of age, and establishment of cubic-foot yields in relation to age, site index, and stand density.

Cubic Volume Table Construction

A volume table was constructed from a separate study involving 324 trees. Sample trees were measured to a top diameter outside bark of 4 inches. The data were then subjected to multiple regression analysis; the cubic-foot volume equation developed by this analysis was calculated to be:

Equation 1:

$$\text{Merchantable volume outside bark in cubic feet} = 1.237977 - 0.111164\,H - 0.250482\,D + 0.025574\,DH - 0.007355\,D^2 + 0.001358\,D^2H$$

where,

H = total tree height (in feet)

D = diameter at breast height outside bark (in inches)

Equation 1 accounted for 98 percent of the variation about the mean. Volumes calculated by this equation appear in table 1.

Table 1. --Merchantable volume outside bark of Virginia pine in cubic feet to a top diameter outside bark of 4 inches (from equation 1)

D. b. h. (inches)	Total height in feet							
	25	35	45	55	65	75	85	95
	Cubic feet							
4	0.4	0.6	0.7	0.8				
5	1.1	1.6	2.1	2.6	3.1			
6	1.8	2.7	3.6	4.5	5.4	6.3		
7	2.5	3.8	5.2	6.5	7.8	9.2	10.5	
8	3.3	5.1	6.9	8.7	10.5	12.3	14.1	15.9
9	4.1	6.4	8.7	11.0	13.3	15.6	17.8	20.1
10	5.0	7.8	10.6	13.4	16.2	19.0	21.8	24.6
11		9.3	12.6	16.0	19.3	22.7	26.0	29.4
12		10.9	14.8	18.7	22.6	26.5	30.4	34.3
13		12.5	17.0	21.5	26.0	30.5	35.1	39.6
14		14.2	19.4	24.5	29.6	34.8	39.9	45.0
15		16.1	2: 3	27.6	33.4	39.2	45.0	50.7
16			24.4	30.9	37.3	43.8	50.2	56.7
17				34.2	41.4	48.6	55.7	62.9
18				37.8	45.6	53.5	61.4	69.3
19					50.0	58.7	67.3	76.0
20					54.6	64.0	73.5	82.9

Site Index Curves

Site values used in relating yield to site quality were developed from height and age data collected on each sample plot plus an additional small number of plots not represented in the yield analyses.

Site index curves based on an index age of 50 years were constructed using the coefficient of variation method as described by Osborne and Schumacher (4), and appear in figure 4 (1). Although a relationship existed between density and site index, the maximum corrections for density were too small to be given consideration. Examination of the data indicated that the regression of logarithm of height over the reciprocal of age was linear and solution by the regression method would have produced similar curves.

To establish the site index of Virginia pine within the area sampled, it is only necessary to determine the age and the average height of the dominant and codominant trees and apply this information to the curves in figure 4.

Selection of Yield Plots

The distribution of yield plots in relation to age and site index is shown in table 2. Generally, two sizes of plots were used. If the stand contained more than 800 trees per acre, the plot size was one-tenth acre; if stands contained less than 800 trees per acre, quarter-acre plots were established.

Table 2.--Distribution of yield plots by age and site index

Site class	Age class (years)					
	10 to 20	20 to 30	30 to 40	40 to 50	50 to 60	Total
			Number of plots			
50	1	2	--	--	--	3
60	28	30	14	5	1	78
70	21	25	8	6	3	63
80	4	8	4	1	--	17
Total	54	65	26	12	4	161

Plot Measurements

The following data collected at each plot location were of importance in the development of the final yield equation:

1. Sample tree measurements. Ten trees of Virginia pine (or fewer if less than 10 trees were present on the plot) were systematically selected as sample trees. The age of each sample tree was determined by increment borings or, with small sample trees, by felling the selected trees. Total height was also obtained for each sample tree.

2. Stand tally by species and 1-inch diameter classes.

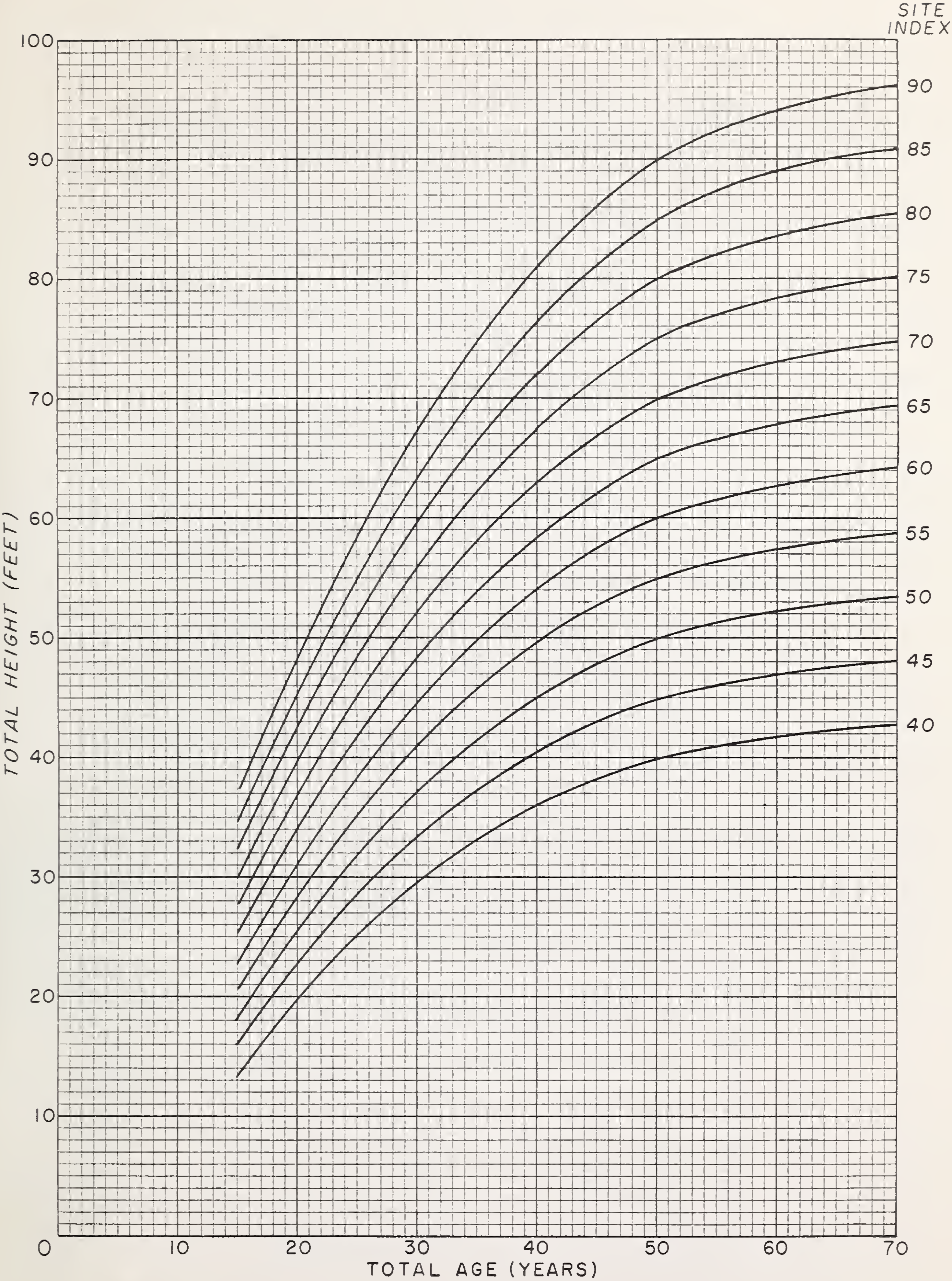


Figure 4.--Site curves at an index age of 50 years for natural stands of Virginia pine in Maryland and the Piedmont of Virginia and the Carolinas.

Calculation of Plot Volumes

Cubic foot per acre volumes were computed for the Virginia pine occurring on each plot. As a first step in this computation, a graph was prepared for each plot showing total height of the Virginia pine sample trees plotted over their diameters at breast height. These curves furnished a plot-by-plot estimate of the tree height-tree d.b.h. relationship. Per tree volume estimates for each d.b.h. class on each plot were then obtained by reading the estimated total heights from the proper height-over-diameter curve and selecting values from the cubic-foot volume tables described previously. Summations of the individual tree volumes within the plot were expanded to a per-acre basis.

Determination of Density Standards

In order to obtain precise prediction equations for yield, stand density must be measured and its effect on yield estimated. Eighty-one plots, representing conditions of average dense stocking in which Virginia pine composed at least 75 percent of the basal area, were chosen as a base for stocking. Regression analysis related total basal area per acre of all species on these plots to average stand age and site index. The regression equation derived in this analysis is shown below:

Equation 2:

$$\text{Logarithm of total basal area per acre} = 2.082746 - 4.005109(1/\text{Age}) + 0.002856\,(\text{site index})$$

This regression accounts for 83.01 percent of the variation in basal area among the 81 sample plots.

With equation 2 it is possible to predict what basal area would be considered average dense stocking for any combination of stand age and site index. Solutions of equation 2 for various combinations of age and site are given in table 3.

Table 3.--Average dense stocking in basal area per acre

Stand age (years)	Site index (feet)			
	50	60	70	80
	- - - - Square feet - - - -			
10	67	71	76	81
15	91	97	104	111
20	106	113	121	129
25	116	124	133	141
30	124	132	141	151
35	129	138	147	157
40	134	143	152	163
45	137	146	156	167
50	140	149	159	170
55	142	152	162	173
60	144	154	164	176

With the aid of table 3, the density of any given stand may be easily determined. As a first step, stand age and site index are established and the basal area of average dense stocking is obtained from the table. Density percent is then calculated as 100 times the ratio of actual total basal area per acre of all species to the basal area of average dense stocking.

Statistical Analysis

Using the logarithm of the per acre Virginia pine volume as the dependent variable (Y), multiple regression techniques were applied to data from the 161 plots to develop a yield-predicting equation based on functions of stand age, density, composition, and site.

The regression analysis indicated the following variables to be of significant importance in predicting Virginia pine yields:

the reciprocal of average stand age squared,
the logarithm of density percent,
the logarithm of percent composition where percent composition is defined as 100 times the ratio of Virginia pine basal area per acre to the total basal area per acre of the entire stand,
site index (average height of dominants and codominants at age 50).

These variables were then used to develop the final regression equation shown below:

Equation 3:

$$\text{Logarithm yield (merchantable volume outside bark in cubic feet)} = 0.098451 - 0.030055\left(\frac{100}{\text{Age}}\right)^2 + 0.28752(\text{log. density}) + 0.72820(\text{log. composition}) + 0.0236009(\text{site index})$$

Equation 3 accounts for 81 percent of the sample variation in merchantable cubic-foot yields. Solutions of equation 3 for pure Virginia pine stands of various densities and ages over a variety of sites are given in table 4.

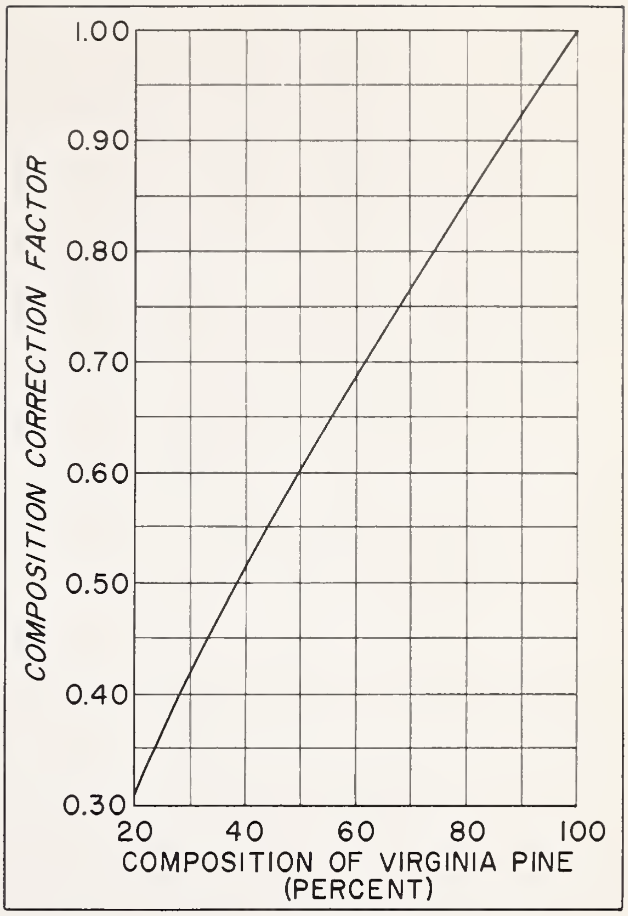
For mixed stands, estimates of Virginia pine yields can readily be obtained by the use of composition correction factors (fig. 5). First, compute the ratio of Virginia pine basal area per acre to the total per acre basal area of the entire stand. The corresponding composition correction factor can then be selected from figure 5. Multiplication of the appropriate tabular yield value by the composition correction factor will give the corrected yield estimate. For example, a stand on site 60, age 50, 100 percent density with 60 square feet of Virginia pine per acre out of a total of 149 square feet basal area would have a 40 percent composition of Virginia pine. From figure 5, the composition correction factor would be 51 percent. The tabular yield value (table 4) would thus be reduced from 2,665 cubic feet per acre to approximately 1,359 cubic feet.

Table 4.--Yield tables for pure stands of Virginia pine in cubic feet per acre (outside bark) of merchantable volume[1]

Age (years)	Percent density					
	20	40	60	80	100	120
	- - - - - -	- - - - - -	- - - Cubic	feet - - -	- - - - - -	- - - - - -
			SITE 55			
20	299	365	410	445	475	500
30	782	954	1,072	1,165	1,242	1,308
40	1,094	1,336	1,501	1,630	1,738	1,832
50	1,279	1,561	1,754	1,905	2,031	2,140
60	1,391	1,699	1,908	2,073	2,210	2,329
			SITE 60			
20	392	479	538	584	623	657
30	1,026	1,252	1,407	1,528	1,629	1,717
40	1,436	1,753	1,969	2,139	2,281	2,403
50	1,678	2,048	2,301	2,499	2,665	2,808
60	1,826	2,229	2,504	2,720	2,900	3,056
			SITE 65			
20	515	628	706	767	818	862
30	1,346	1,643	1,846	2,005	2,138	2,253
40	1,884	2,300	2,584	2,807	2,993	3,154
50	2,202	2,687	3,019	3,280	3,497	3,685
60	2,396	2,925	3,286	3,569	3,806	4,011
			SITE 70			
20	676	824	926	1,006	1,073	1,131
30	1,766	2,156	2,422	2,632	2,806	2,957
40	2,472	3,018	3,391	3,683	3,928	4,139
50	2,889	3,526	3,962	4,304	4,589	4,836
60	3,144	3,837	4,312	4,684	4,994	5,263
			SITE 75			
20	886	1,082	1,216	1,320	1,408	1,484
30	2,318	2,829	3,179	3,453	3,682	3,880
40	3,245	3,960	4,450	4,833	5,154	5,431
50	3,791	4,627	5,199	5,648	6,022	6,346
60	4,126	5,036	5,658	6,146	6,553	6,906
			SITE 80			
20	1,163	1,419	1,595	1,733	1,847	1,947
30	3,041	3,712	4,171	4,531	4,831	5,091
40	4,257	5,197	5,839	6,342	6,763	7,126
50	4,975	6,072	6,823	7,411	7,902	8,327
60	5,414	6,608	7,425	8,065	8,599	9,062

1/ Merchantable volume of all stems 4 inches d. b. h. and over to a top diameter outside bark of 4 inches.

Figure 5.--Virginia pine composition correction factors for use with table 3.



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